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PAPER MILL IN BALAKHNA NEAR NIZHNI-NOVGOROD

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[Diagrams referred to herein are not reproduced.]

The great tasks assigned to the industry of the USSR resulted in a tremendous upswing in the building industry and in the erection of the most diversified factories and plants. Achievements in this field are probably well known. The construction of a large number of factories was begun even before the Five-Year Plan was initiated. The motivating force had been shortage of various goods and materials. The construction of several large paper mills in particular was started at the end of 1925. Paper consumption in Russia before World War I was small in comparison with western Europe and America. It hardly exceeded 4-5 kg per person per year. Of these requirements 72.5 percent was satisfied by domestic paper mills and the rest was covered by imports. After the war, the number of paper mills decreased greatly as a result of the creation of various border states within whose bounds these paper mills were located. Among others, all Finnish mills were lost and these had almost completely met the Russian newsprint requirements in the prewar era.

After the Revolution, the increasingly developing public consciousness called for a corresponding increase in newspaper publication. But the paper shortage was a great obstacle to this. At the end of 1925, this circumstance and the necessity of restricting imports of less valuable commodities so far as possible led to the aforementioned decision to construct several large mills, particularly for low-grade paper, including newsprint. Among these was a large central Russian paper combine, located in Balakhna on the Volga, 400 km from Moscow. The proximity of large forests was one determining point in the choice of the building site. These forests can furnish the mill over long periods of time with its wood requirements for manufacturing

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and heating purposes by floating the logs on one of the largest rivers of Europe. The location on the Volga which can supply the water necessary for paper manufacture and the proximity of an overland power plant near Balakhna were also determining factors in the ultimate choice of building site. It was decided to erect there a large combine for the manufacture of cellulose and paper and to equip it with the largest and most modern machines. A plan for the plant installation was drawn up calling for a yearly production of 85,000 tons of wood paste, 36,000 tons of cellulose, and 110,000 tons of newsprint. Construction of the mill started in 1926 and a part of it is already in operation.

Diagram 1 presents a general view of this large mill as of 1929. A large paper machine supplied by the Voith firm in Heidenheim on the Brenz River is already in operation. This machine has a working width of 6,000 mm and a speed of 300 mm per minute. A second machine of the same size but of American make is being assembled and will soon be put into operation.

Another large building will be erected in the summer of 1930 for a third machine of the same dimensions and for a wrapping-paper machine. Each of these three machines will produce 105-112 tons of newsprint daily. In this way the Balakhna mill will be the largest newsprint mill in Europe.

In taking up the question that interests us particularly, i.e., factory buildings, we note that both the type of construction and the dimensions of the buildings to be erected demanded a durable type of structure. Therefore, buildings of ferroconcrete were erected for the most part. However, bricks were selected for the masonry since they could be obtained inexpensively and in adequate amounts from the many nearby brickyards. When the choice of building materials was being made, iron too was taken into consideration but it was rejected because it was considerably more expensive than ferroconcrete. Modern wooden structures could have been used for some of the buildings but the fire regulations then in force prevented this. Wood was used only for secondary and small buildings. Since the views on this subject have been somewhat changed, wooden structures may now be considered for large factory buildings too. In order to give an idea of the size of the Balakhna structure, we mention that the cubical content of the main buildings amounts to 400,000 cubic meters and the following materials were used in constructing it: 40,000 cubic meters of concrete, 4,500 tons of iron, and 12 million bricks.

In addition to the factory buildings proper, a workers' settlement for about 5,500 persons was erected.

A description of the factory buildings follows. These are of interest both from a technical standpoint and because of their size.

A considerable number of the larger buildings could not be constructed without proper mechanical equipment. In 1926 we had a number of difficulties in this respect since we had no building-machine factories of our own and there were only a few obsolete and worn-out machines in Russia at that time. For this reason some building machines had to be imported from Germany. Among these were concrete mixers from the Urals Works corporation, mortar-mixing machines from the Burger Corporation, sand and gravel washers from the Sonthofen Metallurgical Plant office, Romryk and Rekord iron-cutting and bending machines from the Futura factory, tower cranes from Kaiser & Schlaudecker, gunite machines, etc.

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The two tower cranes pictured in Diagram 11 are the first to be used in the USSR. Various other machines and equipment such as winches, hoists for bricks, pumps, motors, etc., were supplied by domestic plants.

The large number of different buildings and the great variation in the live load led to the employment of very different types of construction in developing the project. In addition to the usual ferroconcrete ceilings for live loads of 250 kg per sq m to 2,500 kg per sq m, mushroom system ceilings with a span of 6.20 m were constructed for a live load of 2,000 kg per sq m. In addition, the following types of construction were carried out: large plant structures, arched roofs, story frames, wood chip silos, girder frames for passages between individual factory buildings, various tanks, vats, machine bases, lime towers, etc.

The foundation of the buildings in general presented no difficulties since the ground consists of medium-grained sand on which the foundations could be directly erected. In individual cases where the load was heavy, strip foundations had to be laid under the posts which were calculated as supports on an elastic base.

A detailed description of all the factory buildings would take up too much space. Therefore, we shall restrict ourselves in the following account to a description of the largest and most interesting. At the same time we note that the necessity of building as economically as possible demanded a careful working out of the projects and exact statistical computation. The most modern statistical methods were employed. The goal was, in many cases, light construction, but it conformed in all respects to safety requirements. In the following we shall discuss briefly some details of the calculation methods employed which are of interest. The computation for ferroconcrete structures was made according to regulations prevailing in the USSR, published in Manual for Ferroconcrete Construction, Vol IX, 3d edition. According to these regulations, the concrete must rate 45 kg per sq cm under centric pressure and 50 kg per sq cm under bending stress. The iron must rate 1,200 kg per sq cm. Portland cement with a rating of up to 300 kg per sq cm was used for the ferroconcrete work.

The main factory building is the paper-machine building which houses two machines of the above dimensions. It is a two-story building, 120 m long and 37.26 m wide. The lower story is 4.00 m high, the upper story, 10.90 m. The construction of this building can be seen from the cross section shown in Diagram 2 and the reinforcement plan of the main framework shown in Diagram 3. This framework construction was computed entirely as such. The live load of the inserted ceiling was taken as 1,200 kg per sq cm but individual sections of it had to bear a heavier load and had to be built stronger in proportion. Powerful girders on two longitudinal members of the floor support the paper machine and carry a load of 12 tons per meter. Posts are set up at intervals of 6.00 meters. Two expansion joints divide the whole building into three parts, each 40.00 m in length. There is a 15.00-m steam exhaust shaft over the central section. The heavy ferroconcrete construction of this shaft, aswell as the wind pressure on it, required a proportionate strengthening of this part of the building. A Rabitz ceiling was built under the framework bolts of the main structure so that all steam may be carried off without obstacle through the shaft. This ceiling was made by a sprayed concrete process which made it possible to achieve the required thickness. Each room of the building contains two cranes with a capacity of 20 and 30 tons respectively. The heavy posts of the

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[illegible] post on strip foundations which for the floor 2.5 kg per sq cm. The original plan had been to erect all seven posts on a continuous strip foundation but the idea had to be given up to make room for longitudinal air channels. After the foundations had been completed, the original ventilation plan was rejected and the plan of the Schreider firm in Karlsruhe was accepted. This plan did not provide for underground air channels. Thus the three separate strip foundations remained, as shown in Diagram 2, although a continuous strip foundation would probably be more suitable. Diagram 4 shows an inside view of the paper machine room. An outside view is given in Diagram 8.

[illegible] from the paper machine room to the packing room and the paper storehouse by two passages with a 15-m span. Their supporting structure consists of two girders each. This is also a two-story building. A cross section and an inside view are presented in Diagrams 5 and 6. The heavy load of the inserted ceiling -- 2,000 kg per sq m -- and the low height of the lower story -- only about 4 m -- were responsible for the use of the mushroom system ceiling as the most suitable type of construction in this case. This ceiling was computed by means of the Marcus process of substitute frame since the rectangular shape of the panels (6.20 x 5.20) did not permit simpler computation by means of the Lowe tables. Diagram 7 shows the heavy reinforcement of this mushroom system ceiling. The roof, as is shown in Diagram 5, is a framework construction and has no peculiarities in other respects. Diagram 8 shows the packing room in the foreground and the paper-machine room in the background.

The second large building of the factory is the digester plant. The supporting structure is formed by 42-meter-high story posts which support the wood chip silos. These silos have a [illegible] 20 x 11.40-meter cross section and a volume of 320 cubic meters. The framework of this building stands on a platform of longitudinal and latitudinal sections in reinforced concrete. This type of foundation construction had to be used since the ground here was somewhat weaker and would permit a maximum load of only 1.5 kg per sq cm. The employment of the open-work foundation permitted a fairly even distribution of the weight of the structure on the ground. This is illustrated in Diagram 13. The somewhat greater ground load beneath one of the uprights on the left denotes a better ground condition in that place, as was confirmed by test loading. This type of foundation proved completely appropriate and, in addition, cheaper than using concrete piling, a method also taken into consideration.

The construction of this building is illustrated in Diagrams 9 and 10. Its general appearance may be seen from Diagram 11.

The digester bases are set in the individual cells formed by the reinforced concrete sections in the building foundation. These bases are in the form of thick concrete blocks. The lower part of these blocks has been rendered in such form that they can settle entirely independently of the building proper. Because of the high ground pressure, piling made of concrete set under high pressure had to be used under three of these blocks.

This rather important structure also required a suitably accurate statical computation for its construction. Since the statical computation of the story posts presents no peculiarities, we will leave it and proceed to a brief description of the computation process for the foundation and the wood chip silos.

The open-work foundation, consisting of longitudinal and latitudinal sections, was considered, in computing, as a uniform whole resting on an elastic bearing surface. [illegible] thereby designated as 3 kg per cubic centimeter. The pattern for computation with load, strength and moment figures is presented in Diagram 12. The loads which are transmitted to the longitudinal section are taken as indefinite static quantities. Use of the D-U process (TN: possibly Bow's notation) reduced the task to the solving of 12 standard equations. After finding a value for the indefinite static quantities, each section could be computed separately as a beam resting on an elastic surface. Diagram 13 shows the computer's figures for ground pressure, and Diagram 14 the bending moments for longitudinal section II, where section II lies on the windward side. The moment curve presents a picture which could hardly have been obtained through elementary methods.

The wood chip silos were considered as a three-dimensional system, covered by a [illegible] elastic netting. The usual differential equations were set up representing the relations between the ordinates of the silo sides' bending surfaces. In addition, equations were developed for the groin points. These equations express the relation of the moments and angles of torsion (winkeldrehungen) at the joints of the adjacent surfaces. In this way, the equations necessary for working out the problem were obtained. The moments and stresses in the sides were computed after the solution of these equations. The results of this computation are presented in Diagrams 15 and 16. It can be seen from this that the elementary calculation which, so far as we know, is predominantly used for the computation of the silo cone, yields totally unsatisfactory results. In our computation, we obtained much lower moment quantities, and also a totally different pattern for their distribution. The same applies to the stresses in the sides. The whole weight of the cone is transmitted partially to the horizontal frames supporting it, and in part, directly onto the columns. In our case, this latter part amounts to approximately 24 percent of the total weight of the cone. The load on the horizontal frame is not uniform but follows approximately a three-cornered pattern as does also the horizontal load of the frame itself. The correct valuation of the moments and stresses applying to the bunker sides permitted the reduction of the strength of the sides to a minimum. The sides are actually 11-15 cm thick. In view of the large dimensions involved, this is proportionately little in comparison with many other types. Each bunker holds approximately 320 cubic meters of chips. Its full load amounts to 150 tons. The iron reinforcement was distributed commensurate with the course of the moments and the stresses. The bunkers are illustrated in Diagram 17. The correct distribution of the loads on the supporting framework also has had a favorable influence on their dimensions.

Diagram 19 shows an inside view of the filter building for waste water from the paper machine. The filter itself is a tank 45 meters long, 10.50 meters wide, and 6 meters deep, divided into two sections by a longitudinal wall 0.60 meters thick. The building proper has brick walls supporting an arched roof, clearly illustrated in Diagrams 18 and 19. This type of construction was chosen in order to light the interior by means of windows above the side of the filter.

The pump house and water-purifying plant is a comparatively smaller structure. Its cross sectional aspect is shown in Diagram 20. It pumps 3 cubic meters of water per second into the factory. Because of the rather great water pressure to which it is subject during high-water periods, the building is constructed entirely of concrete and reinforced concrete. The building was erected in winter during the time when the water level was at its lowest point. Work was carried on in a construction pit walled around

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with sheet piling. In one depression, a layer of quicksand was struck. The rush of water was so great that it could be pumped out only with great difficulty, and much sand was washed away. A water-settling installation was contrived and operations proceeded rapidly and without difficulty. The high transverse wall in the center of the building had to be set on concrete piling since the sand here was loose, making direct seating impossible. Diagram 21 shows the exterior view of the pump house. From this and the other views of the factory buildings, it can be seen that the architectural aspect in the building of these structures was not neglected. A simple architectural method succeeded in imparting a pleasant appearance to all of the buildings.

Many other factory buildings such as the power station, wood paste factory, repair shops, etc., will not be described, although they could offer several interesting points. We will describe further only the lime towers pictured in Diagram 22. Up till now, towers of this type in pulp mills were made of wood; only in recent years have there been many instances of a changeover to the use of reinforced concrete for the construction of lime towers. But such structures are already quite numerous in America, Germany, and Finland. Our towers are the first of the reinforced concrete type in Russia, and this [type] was chosen because it offers considerable advantages in using the towers. We were allowed to use this type of construction on condition that it costs no more than wood. Since the armature accounts for practically the major part of the expenses in the building of high structures -- 40 meters in our case -- we planned primarily to use such methods which require a minimum of armature. Our purpose would easily be accomplished by using hollow concrete blocks as is the practice in building lime towers in Germany. The method is also much used in the construction of chimneys. However, we had no experience no blocks handy, and also little time to make the blocks between the time when building permission was granted and the time construction was to start. The second possibility was to use flexible casing (bewegliche Schalung) which has proved satisfactory in numerous silo constructions in the USSR. However, it was necessary that the towers be conical rather than cylindrical, in which case the use of flexible casing meets with several difficulties. Our towers have an outside diameter of 3.96 meters at the bottom and 3.56 meters at the top. This form was chosen to prevent scaffolding when being filled with limestone.

For all of the reasons mentioned above, we chose a method using an ordinary casing, only taking care that the armature be minimized as much as possible. Both towers stand on a massive concrete block which has a 15 x 9.60-meter cross section and is 3.50 meters deep. In forming this block, nets of 10-mm iron rods were laid in every 50 cm; and to attain a firm connection with the foot of the tower itself, 12-mm iron rods were set vertically in the concrete. The sides of the towers are 20 cm thick at the bottom and 10 cm thick at the top, and are made in the usual manner with circumferential and vertical iron reinforcement. They were calculated for the actual weight of the structure, the wind pressure, and the internal pressure of the stone burden. On top of the towers is a structure providing space for elevator winches and several apparatus, and from which they are serviced. This area is reached by wooden steps supported by the tower walls. The elevator shaft is located between the stair frames.

In order to protect the concrete from the sulphurous acid, the inner surface was covered with a sprayed-on concrete coating consisting of slag cement, chamotte powder, and chamotte sand. A covering

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of 50-mm-thick acid-proof plates set in chamotte was placed over this. The seams were filled in with a putty made of litharge and glycerine.

During construction, the simplest scaffolding was used. This consisted of four posts, 20-25 cm thick for each tower. These were held fast by 12-mm cable guys. In the beginning, these were erected to a height of 19.20 meters, and guide rings were fastened to them at intervals of 6.40 meters. Upright boards were fastened edgewise to the guide rings, and the actual casing of bowed 10-mm boards was fastened to them [the upright boards]. In this way, the outer casing was erected first of all; then the iron reinforcements were set up, and finally, the inner casing. The sequence of operations was as follows: simultaneously, one 6.40-meter section was concreted, the next higher section received the iron reinforcements, and the casing was erected in the third section; along with this, additional posts were erected and made fast with cable. This type of forming may be seen in Diagram 23.

The wooden steps were erected along with the towers.

All materials were hoisted up to 25 meters by the tower crane, and above that by the lift which, meanwhile, had been erected in the shaft.

The costs of construction by this method did not exceed those of a wood construction job.

The entire procedure required approximately seven weeks. Diagrams 24 and 25 show views of the smaller slasher buildings where the tree trunks floated in are cut up by a system of circle saws. The heavy machinery is mounted on bases of reinforced concrete. The upper level is of wood construction formed of posts and longitudinal beams. The two cross members on the beams between the posts are formed by boards nailed together. This construction is extremely simple, easy, and particularly cheap when the boards from the casings are used, as was done in this case.

Diagram 25 also shows a reinforced concrete truss which absorbs considerable stress from the connecting wood conveyor belt.

The project was worked out in a special designing office organized for the purpose by the Central Trust for Paper Manufacturing, and was under the direction of the writer of this article.

In closing this short description of several buildings and structures of the factory in Balakhna, we wish to note that this is the first large paper mill in the USSR, but not the last. In the near future we will begin construction on a number of similar plants, some of which are to be even larger.

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